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Design and Analysis of Flapping Wing Combination with Quadcopter UAV

S. Mahendran*
Assistant Professor, Department of Aeronautical Engineering, Hindustan Institute of Technology and Science, Chennai

R. Asokan
Professor, Department of Aeronautical Engineering, Hindustan Institute of Technology and Science, Chennai

Abstract- **A hybrid Unmanned Aerial Vehicle (UAV) or hybrid drone is an evolved version of a standard UAV. The design of such a model is developed as a solution to the problems faced in the industry which mainly include endurance and payload. The effective design of a hybrid UAV contributes to the developments targeted to increase the endurance and payload properties of the UAV. The customary flapping wing UAVs can fly for significant distance however require runways or vast areas for take-off and landing. Then again, the more moving multirotor UAVs are very flexibility yet can't be utilized for significant distance flights in light of their more slow velocities and somewhat higher utilization of energy. This review proposed the execution of cross breed VTOL UAV which has the moving benefit of a multirotor UAV while being able to go quick to arrive at a further distance. The plan procedure and manufacture strategy are examined widely which would be trailed by various flight tests to demonstrate the idea. The proposed UAV would be furnished with quadcopter engines and a flapping wing mechanism engine for vertical and even flight modes separately. Model B is having less drag when comparing model A about 29% and Model C about 4%. The lift coefficient value is higher in model B when compared to other models with about 28% with A and 26% with B.**

Keywords - Drag Coefficient, HUAV, Hybrid UAV, FLAPTOR Unmanned Aerial Vehicle.

INTRODUCTION

Hybrid UAV

Hybrid drones or hybrid unmanned aerial vehicles are advanced versions or models of a UAV. This can be a combination of two or more mechanisms or machines. In our case we decided to combine the functions of a quad copter with an ornithopter to design our hybrid UAV. We believe that properties such as endurance and payload can be improved using this combination. The functioning of the ornithopter wing on the quadcopter frame reduce the power consumption of the battery since the motors are not the only source of thrust. Therefore, improving the weight of the drone with its components. Similarly, different combination of mechanisms is operated together to enhance the performance of the aerial vehicle. We came to our design idea through the hybrid VTOL fixed wing drone. The difference here is instead of the fixed wing we replaced it with a flapping wing structure.[1]

Quadcopter

Quad Copters are one of the most complex flying machines due to its versatility and maneuvering. The control and stability of these vehicles are vital for its operation.[8] Quad rotors are symmetrical vehicles with four equally sized rotors at the end of a body frame made of four equal length rods. By making use of multiple rotors, it allows for greater thrust and maneuvering. Each rotor associated with the quad-rotor helicopter produces both thrust and torque. The front and rear motors both rotate counter-clockwise and the other two rotate clockwise.

Ornithopter

An ornithopter is a craft that uses flapping wing mechanism for lift and movement. The word ornithopter being "bird wing" generates thrust by flapping its wings like a bird. It is designed to derive its chief support and propulsion from flapping wings[3]. At very small sizes ornithopters can be reasonably efficient if well designed. Some ornithopters might be used for covert surveillance as they could pass for birds or large insects if they weren't seen close up. Mainly it is used in military applications such as aerial reconnaissance.[9]The flapping mechanism is to convert the rotary motion of the motor into reciprocating motion of flapping wings. The basis for most mechanisms is a four-bar linkage. There is a rotating crank shaft, driven by the motor. As the crank goes around, the connecting rods push the wings up and down.

The work done in this project is the detail design of a hybrid UAV using the mechanism of an ornithopter and a quadcopter combined name is FLAPTOR (FLAPPING WING+QUADROTOR). The design is then tested for the suitability of flight patterns and basic pitch, roll and yaw maneuvers. In order to get the best possible design for the ornithopter section we designed 3 different designs for the flapping wing. The designs were analyzed for lift and drag coefficients to compare them to each other and select the appropriate design aerodynamically suitable. The design of the Hybrid UAV is done with the help of "Solid works". Analysis of UAV wing orientation to find values of Cd and Cl for different flow velocities is done using Ansys.[4]

LITERATURE REVIEW

There is a limited data to be reviewed in context to the entity we bring into the domain of research and acceptance. The understanding of UAVS in existence, their operations, and skill set. An area of Great explorations towards unique designs and justifying or checking its aerodynamic validity was the main focus of coming up with the approach for our design. Specifications for designing a UAV system based on research data were studied and evaluated.[5]

A virtual simulation environment for validating the control techniques applied to quadcopters. Thus guides us through the simulation process. Further clarity towards the simulation of a designed system. Merging a drone with a balloon and observing endurance and weight compromise. Referential Material for the mathematical models for weights estimation performance analysis, supported with experimental results in different testing scenarios[10]

METHODOLOGY

To design a hybrid UAV with combination of a quadcopter and ornithopter and to analyze its performance aerodynamically. Establishing a real time operation and response of the system in terms of its take-off and landing. The design is to be created in SolidWorks, three different models of wing orientation are designed and analyzed in Ansys under different velocity conditions.[11]The process is carried out for 11 different velocity values and the results are analyzed to select the best orientation of the wing design.

MODEL DESIGN AND ANALYSIS

Design 3D Model

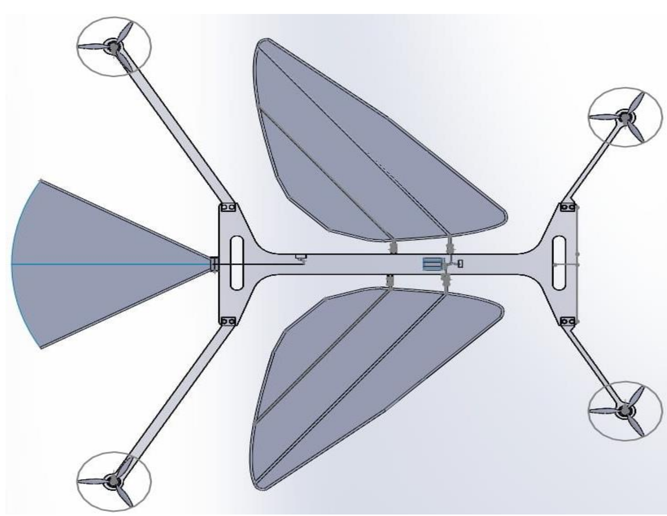


FIGURE 1
MODEL B

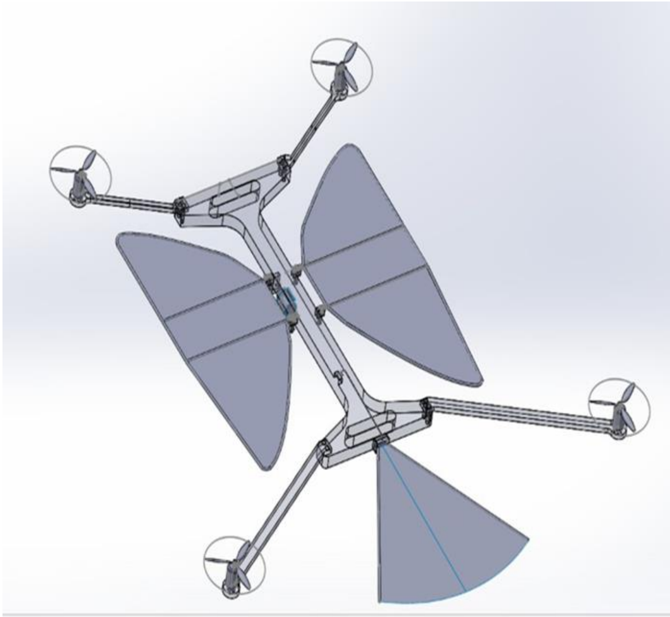


FIGURE 2
MODEL C

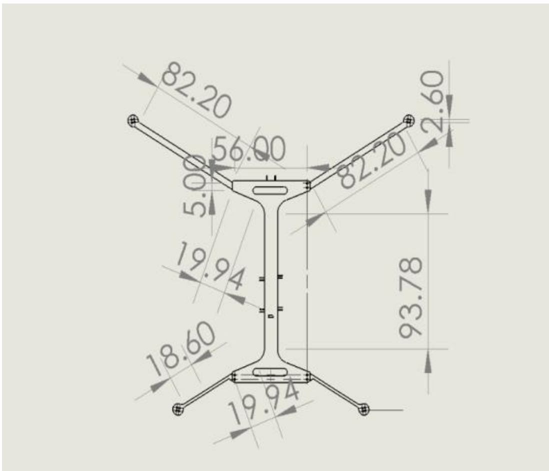


FIGURE 3
BODY FRAME

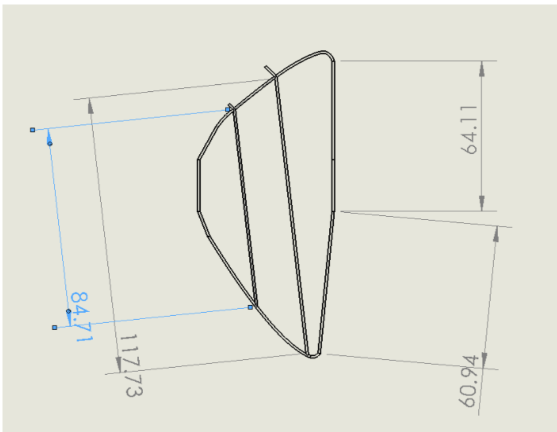


FIGURE 4
WING DIMENSIONS

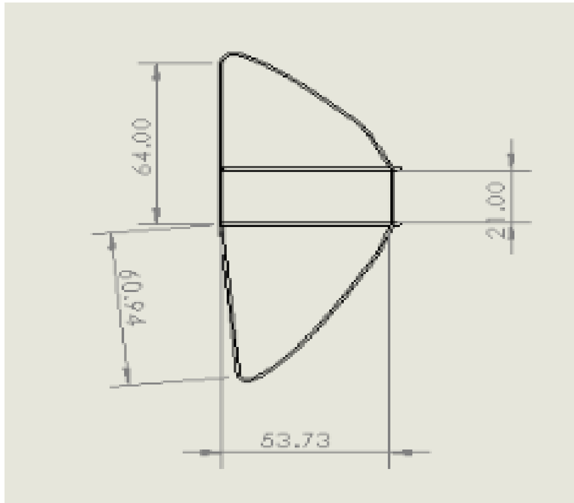
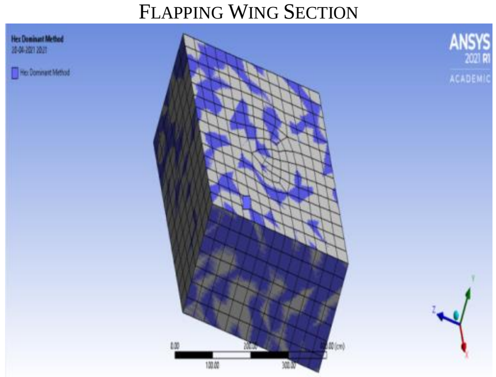


FIGURE 5
FLAPPING WING SECTION



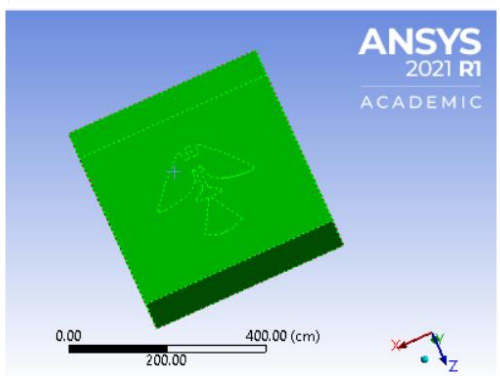


FIGURE 6 AND FIGURE 7: MESHING OF THE MODEL B

Wing Orientations

We designed three different orientations for the wing model of the ornithopter section. Depending on the analysis of the wing models in Ansys Fluent the best suited wing orientation was selected for the hybrid UAV[12]. The models were testing in Fluent with different velocities ranging from 1m/s to 11m/s for all the 3 models and the results for the coefficient of lift and drag values were recorded and compared.

Model A

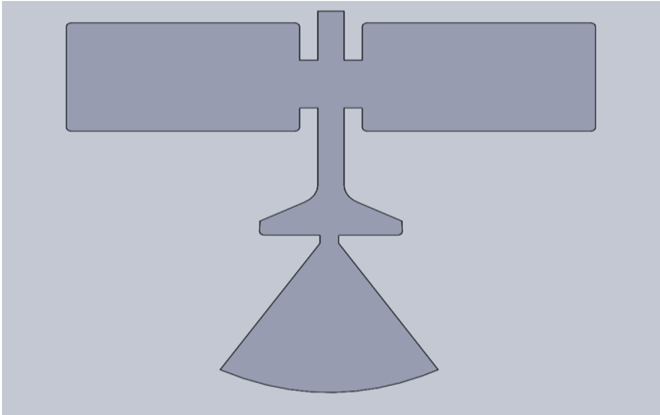


FIGURE 8
MODEL A RECTANGULAR WING CONFIGURATION

Model B

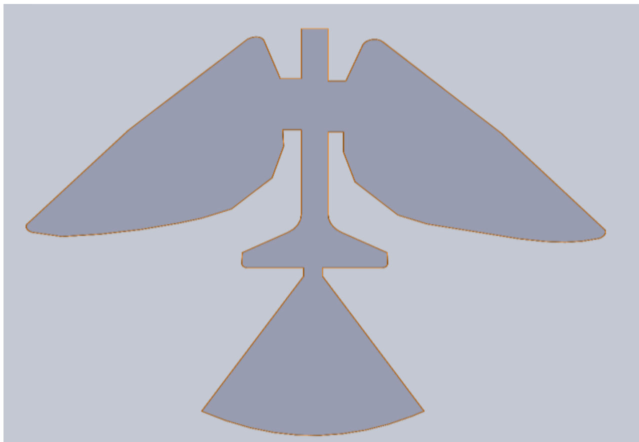


FIGURE 9
MODEL B ELLIPTICAL WING CONFIGURATION

Model C

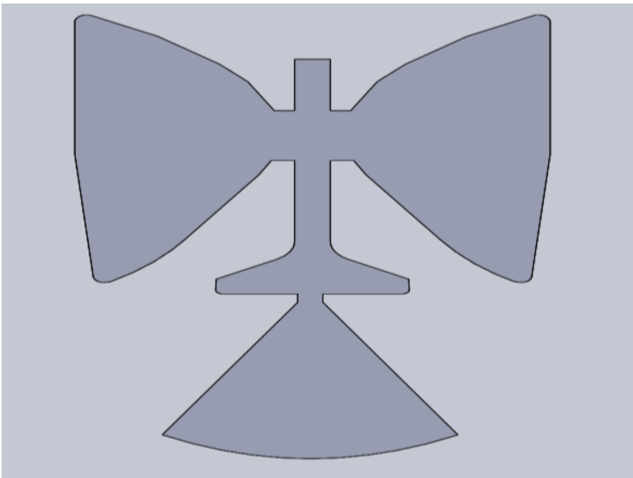


FIGURE 10
MODEL C BUTTERFLY WING CONFIGURATION

The analysis in our project begins with the importing of an external geometry into Ansys fluent, where in this case is the 2D wing design models we made. The “Enclosure” and “Boolean” commands were applied to the geometry. The next step was meshing. In order to obtain a more refined meshing we applied the hexa dominant method. This gave us a refined geometry to understand better about the flow points of our geometry.[6] Under Fluent setup the option for turbulent flow was selected. The inlet velocities were provided and the reference values which were computed from the inlet were taken. Our aim here were to calculate Cd and Cl values for the refined geometry. Under reference dimension command we selected the option for Cd and Cl. In the end we initialized analysis and took down the readings and ran calculations. Cd and Cl graphs were obtained and the value at which the graph converges were taken for our calculations. These values were our final results.

In the graph the x-axis represented the number of iterations in the analysis and the y-axis represent the coefficient of drag (Cd) and Coefficient of lift values (Cl). This was done for each model from velocity 1 m/s to 11 m/s to get the best results possible for all the three models.

TABLE 1
CO-EFFICIENT OF DRAG ESTIMATION

	Cd Values		
Velocity (m/s)	Model A	Model B	Model C
1	0.0085	0.00659	0.0064
2	0.0087	0.00679	0.0066
3	0.009	0.0071	0.0068
4	0.0093	0.0073	0.007
5	0.011	0.0076	0.0073
6	0.0102	0.0079	0.0076
7	0.012	0.00841	0.0081
8	0.0128	0.00901	0.0087
9	0.0139	0.00982	0.0095
10	0.0155	0.01122	0.0109
11	0.0188	0.01413	0.0138

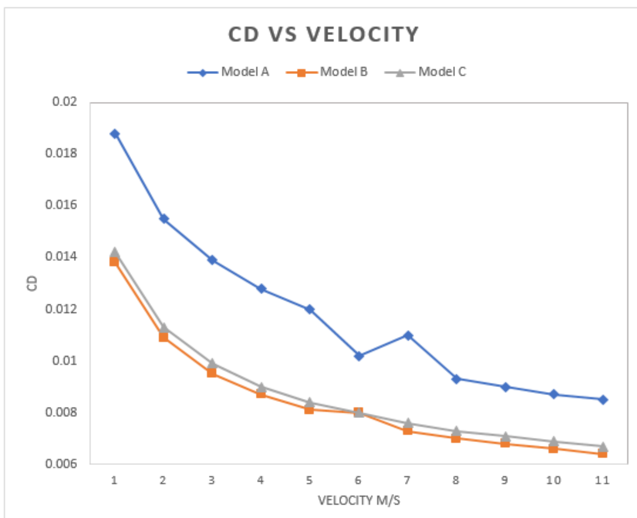


FIGURE 11
CD VALUES GRAPH

TABLE 2
CO-EFFICIENT OF LIFT ESTIMATION

	Cl Values		
Velocity (m/s)	Model A	Model B	Model C
1	0.00659	0.0085	0.0064
2	0.00679	0.0087	0.0066
3	0.0071	0.009	0.0068
4	0.0073	0.0093	0.007
5	0.0076	0.011	0.0073
6	0.0079	0.0102	0.0076
7	0.00841	0.012	0.0081
8	0.00901	0.0128	0.0087
9	0.00982	0.0139	0.0095
10	0.01122	0.0155	0.0109
11	0.01413	0.0188	0.0138

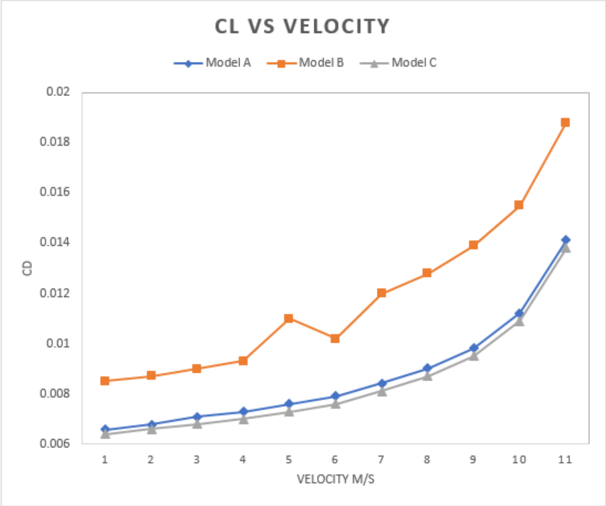


FIGURE 12
CL VALUES GRAPH

CONCLUSION

The graphs provided above shows the value of drag coefficient and lift coefficient for all the three designs[7]. From the analysis of each model under separate velocity conditions, it is shown that model B have the lowest value for drag coefficient. Model B is having less drag when comparing madel A about 29% and Model C about 4%. The lift coefficient value is higher in model B when compared to other models with about 28% with A and 26% with B.Therefore model B is considered as the ideal for the modeling of our hybrid UAV. The model we desided to design should be of less drag values in order to get the best endurance results. Therefore we selected model B to be the design of our ornithopter in our Hybrid UAV.

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